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VIKRAM A SARABHAI COMMUNITY SCIENCE CENTRE

Navrangpura, Ahmedabad - 380 009, India
Tel : +91-79-26302914, 26302085
Email : info@vascsc.org

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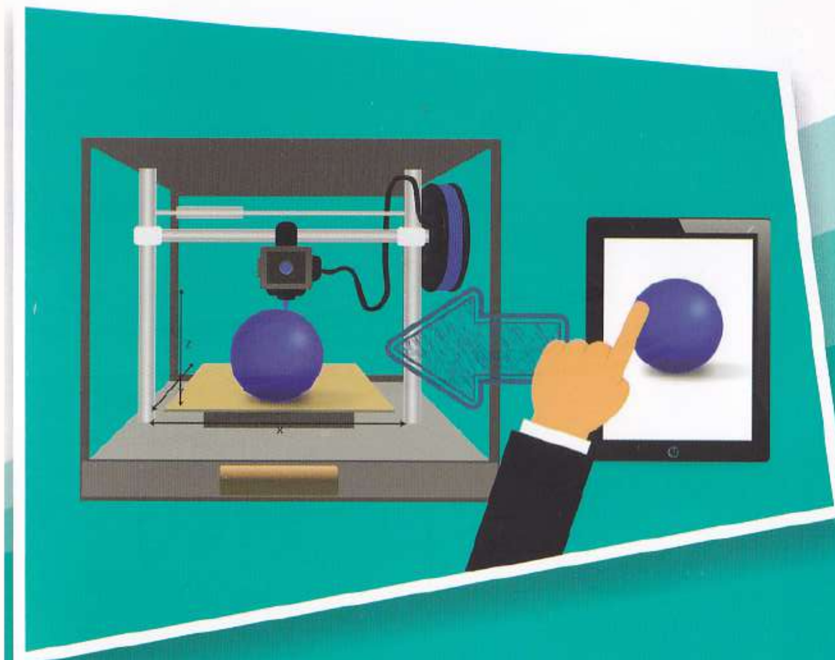
FUNDAMENTALS OF **3D PRINTING** AND **DESIGNING**

Beginner's Guide



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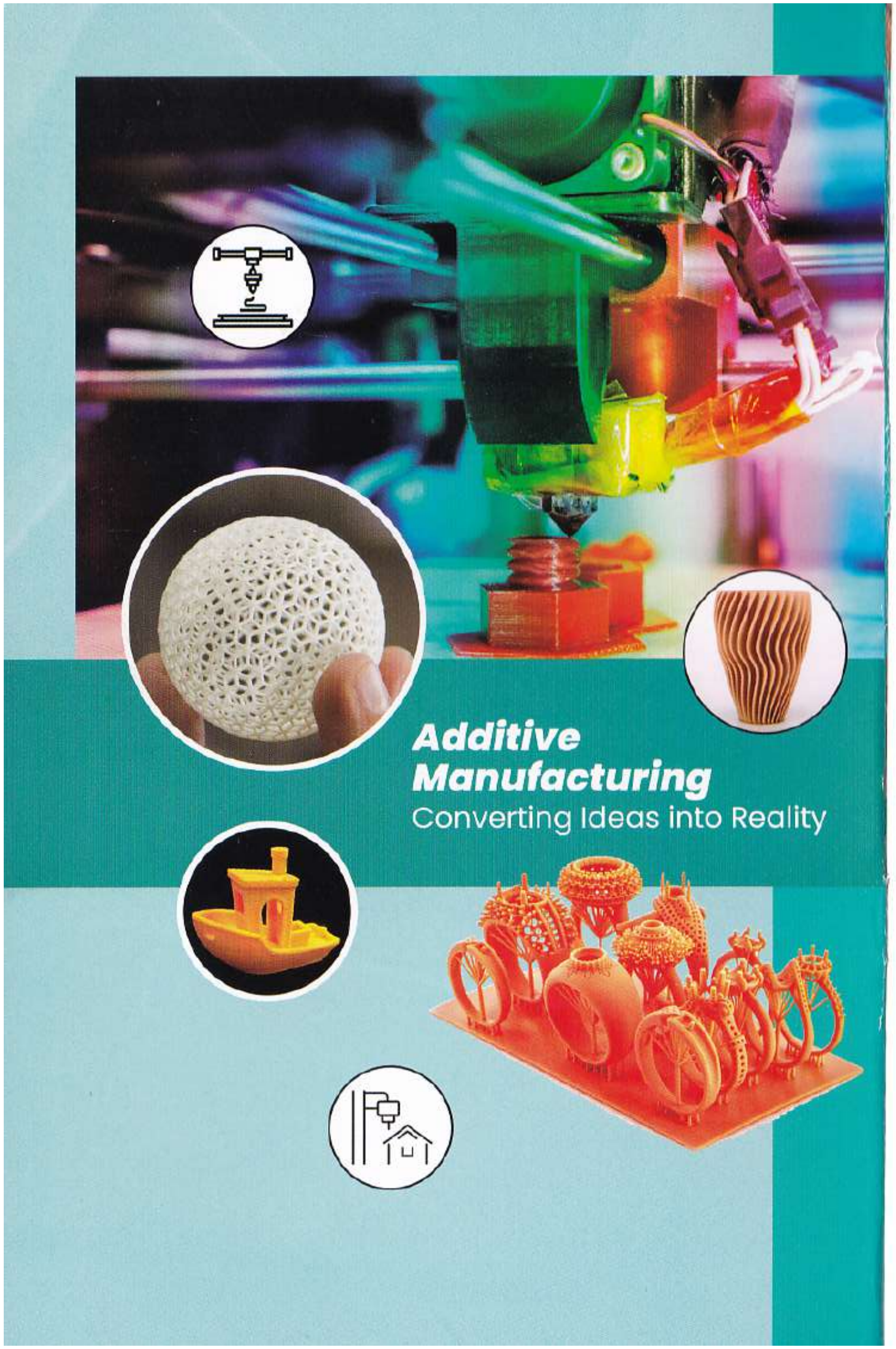

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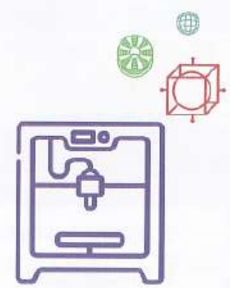

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Contents

Guidance : Dilip Surkar

Development & Writing : Nitin Tiwane, Harsh Bhatt, Sudhirkumar Sharma, Rashika Sitoke

Inputs : Megha Saklani, Megha Parikh

Design : Chetan Patel

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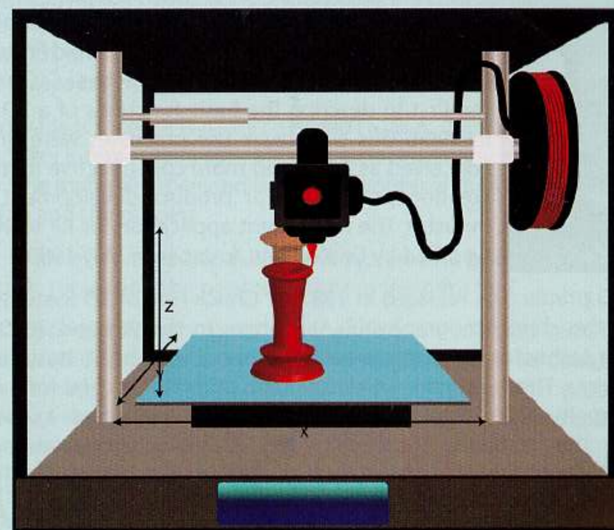
VIKRAM A SARABHAI COMMUNITY SCIENCE CENTRE

Navrangpura, Ahmedabad - 380 009
Tel: +91 79 26302914, 26302085
E: vascsc@gmail.com W: www.vascsc.org

Beginner's Guide to 3D Printing Technology

This resource is intended to be used as a starter's guide into the realm of 3D Printing, one of the most revolutionary technologies of the 21st century. 3D printing has brought about the concept of 'personal manufacturing', because of the option of customization that it brings to the consumer directly. Through this resource, we will try to understand what is additive manufacturing i.e. 3D printing, how it works, process, materials, how to design 3D models using various Computer Aided Design (CAD) Software like TinkerCAD, how to 3D print and its applications.

This resource should preferably be used in conjunction with a laptop or PC, with minimum 4 GB RAM and 2 GB graphic card, preferably with a Windows Operating System.



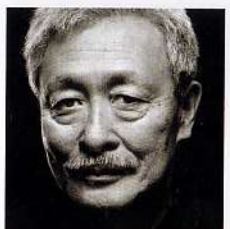
1 Introduction to 3D Printing

3D printing or additive manufacturing is a process of making three dimensional solid objects from a digital file.

The creation of a 3D printed object is achieved using additive processes. In an additive process an object is created by laying down successive layers of material until the object is created. Each of these layers can be seen as a thinly sliced horizontal cross-section of the eventual object.

3D printing is the opposite of subtractive manufacturing which is cutting out/ hollowing out a piece of metal or plastic with, for instance, a milling machine. 3D printing enables you to produce complex shapes using less material than traditional manufacturing methods.

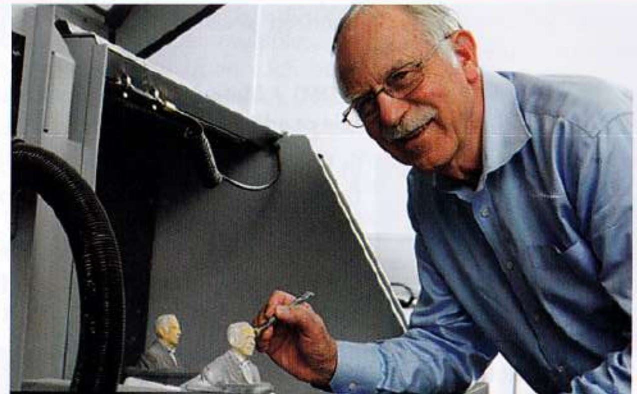
3D printing is an enabling technology that encourages and drives innovation with unprecedented design freedom while being a tool-less process that reduces prohibitive costs and lead times. Components can be designed specifically to avoid assembly requirements with intricate geometry and complex features created at no extra cost. 3D printing is also emerging as an energy-efficient technology that can provide environmental efficiencies in terms of both the manufacturing process itself, utilising up to 90% of standard materials, and throughout the product's operating life, through lighter and stronger design.


Dr. Kodama

The earliest 3D printing technologies first came in the late 1980s, at which time they were called Rapid Prototyping (RP) technologies. The sci-fi author, Arthur C. Clarke, was the first to describe the basic functions of a 3D printer in 1964. This is because the processes were originally conceived as a fast and more cost-effective method for creating prototypes for product development within industry. The first patent application for RP technology was filed by Dr. Kodama, in Japan in May 1980.

The first 3D printer was released in 1987 by Chuck Hull of 3D Systems and it was using the 'stereolithography' (SLA) process. In the 90s and 2000s other 3D printing technologies were released, including FDM by Stratasys and SLS by 3D Systems. These printers were expensive and mainly used for industrial prototyping. In 2009, the ASTM Committee F42 published a document containing the standard terminology on Additive Manufacturing. This established 3D printing as an industrial manufacturing technology. In the same year, the patents on FDM expired and the first low-cost, desktop 3D printers were born, by the RepRap project.

2 3D Printing Technology


Mr. Chuck Hull

The starting point for any 3D printing process is a 3D digital model, which can be created using a variety of 3D software programmes - in industry this is 3D CAD. For makers and consumers there are simpler, more accessible programmes available (e.g. TinkerCAD, Fusion360).

3D objects designed needs to be sliced using a slicing software for converting it to specific printer instructions. Slicing is dividing a 3D model into hundreds or thousands of horizontal layers and is done with slicing software. Some 3D printers have a built-in slicer and let you feed the raw .stl, .obj or even CAD file.

When your file is sliced, it is ready to be fed to your 3D printer. This can be done via USB, SD or internet. Your sliced 3D model is now ready to be 3D printed layer by layer. The material processed by the 3D printer is then layered according to the design and the process.

In most cases of non-industrial 3D Printing, removal of the finished print is a simple task: separating the printed part from the print bed.

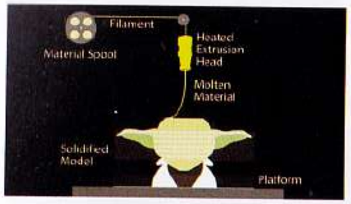
Post processing may vary greatly depending on printing technology and materials used. For example a print made with SLA must be cured under UV, while print made with FDM can be handled right away. Post processing the final product may include high pressure air cleaning, polishing, colouring and other actions to prepare for final use.

There are different types of 3D printing technologies, which process different materials in different ways to create the final object. Functional plastics, metals, ceramics and sand are now all routinely used for industrial prototyping and production applications. Research is also being conducted for 3D printing bio-materials and different types of food.

3 Types of 3D Printing Processes

The ISO/ASTM 52900 standard categorized all different types of 3D printing under one of these seven groups:

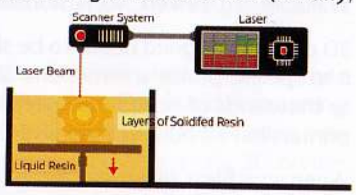
a. Fused Deposition Modelling (FDM) / Material Extrusion : Material is selectively dispensed through a nozzle or orifice.



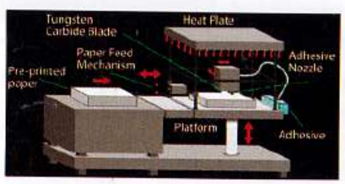
In FDM, a spool of filament is loaded into the printer and then fed to the extrusion head, which is equipped with a heated nozzle. Once the nozzle reaches the desired temperature, a motor drives the filament through it, melting it. The printer moves the extrusion head, laying down melted material at precise locations, where it cools and solidifies (like a very precise hot-glue gun). When a layer is finished, the build platform moves down and the process repeats until the part is complete.

b. Vat Polymerization (SLA & DLP): Liquid photopolymer in a vat is selectively cured by UV light.

SLA and DLP are similar processes that both use a UV light source to cure (solidify) liquid resin in a vat layer-by-layer. SLA uses a single-point laser to cure the resin, while DLP uses a digital light projector to flash a single image of each layer all at once. After printing, the part needs to be cleaned from the resin and exposed to a UV source to improve its strength.



c. Powder Bed Fusion (SLS, DMLS & SLM): A high-energy source selectively fuses powder particles.

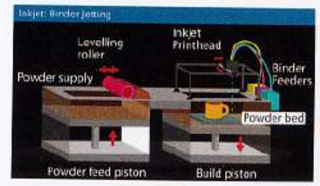


The SLS process begins with heating up a bin of polymer powder to a temperature just below the melting point of the material. A recoating blade or roller then deposits a very thin layer of powder - typically 0.1 mm thick - onto the build platform. A CO_2 laser scans the surface of the powder bed and selectively sinters the particles, binding them together. When the entire cross-section is scanned, the build platform moves down one layer and the process repeats. The result is a bin filled with parts surrounded by un-sintered powder.

d. Material Jetting (MJ): Droplets of material are selectively deposited and cured. Material Jetting works in a similar way as standard inkjet printing.

However, instead of printing a single layer of ink on a piece of paper, multiple layers of material are deposited upon each other to create a solid part. Multiple print heads jet hundreds of tiny droplets of photopolymer onto the build platform, which are then solidified (cured) by the UV light source. After a layer is complete, the build platform moves down one layer and the process repeats.

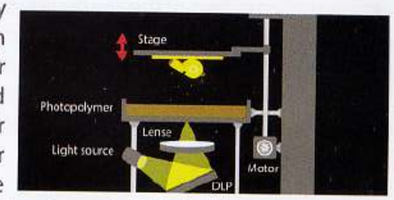
e. Binder Jetting (BJ): Liquid bonding agent selectively binds regions of a powder bed. Direct Metal Laser Sintering (DMLS) and Selective Laser Melting

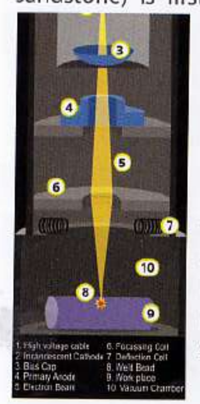


(SLM) produce parts in a similar way to SLS: a laser source selectively bonds together powder particles layer-by-layer. The main difference is that DMLS and SLM produce parts out of metal. SLM achieves a full melt of the powder particles, while DMLS heats the metal particles to a point that they fuse together on a molecular level.

f. Direct Energy Deposition (LENS, LBMD): A high-energy source fuses material as it is deposited.

Binder Jetting is a flexible technology with diverse applications, ranging from low-cost metal 3D printing, to full-color prototyping and large sand casting mold production. In Binder Jetting, a thin layer of powder particles (metal, acrylic or sandstone) is first deposited onto the





build platform. Then droplets of adhesive are ejected by a inkjet printhead to selectively bind the powder particles together and build a part layer-by-layer.

g. Sheet Lamination (LOM, UAM): Sheets of material are bonded and formed layer-by-layer.

Sheet lamination involves material in sheets which is bound together with external force. Sheets can be metal, paper or a form of polymer. Metal sheets are welded together by ultrasonic welding in layers and then CNC milled into a proper shape. Paper sheets can be used also, but they are glued by adhesive glue and cut in shape by precise blades.

4 3D Printing Material

There is a wide variety of material types that are supplied in different states (powder, filament, pellets, granules, resin etc). Specific materials are now generally developed for specific platforms performing dedicated applications (an example would be the dental sector) with material properties that more precisely suit the application.

Plastics

ABS (Acrylonitrile Butadiene Styrene) is a common plastic used for 3D printing, and is widely used on the entry-level FDM 3D printers in filament form. It is a particularly strong plastic and comes in a wide range of colours. ABS can be bought in filament form from a number of non-propreitary sources, which is another reason why it is so popular.

PLA (Polylactic Acid) is a bio-degradable plastic material. It can be utilized in resin format for DLP/SL processes as well as in filament form for the FDM process. It is offered in a variety of colours, including transparent, which has proven to be a useful option for some applications of 3D printing. However, it is not as durable or as flexible as ABS.

Metals

3D printing with metals differs from using plastic, and it takes a couple of different forms. Two of the most common are aluminium and cobalt derivatives. One of the strongest and most commonly used metal for 3D printing is stainless steel in powder form. One popular process, Direct Metal Laser Sintering (DMLS), involves melting metal powders with a laser and layering them together. The process can be used to print anything from jewellery to tools, and even parts for aircraft.

Ceramics

Ceramics are a relatively new group of materials that can be used for 3D printing. However, with these materials post training, the ceramic parts need to undergo the firing and glazing process as in the traditional methods of ceramic production.

Paper

Common everyday copy paper has a place in 3D printing. Using Selective Deposition Lamination (SDL), parts made this way have a feel like wood and are fully colored. Paper 3D prints lack the durability and detail found with PolyJet Resins or gypsum. It is typically used for architectural and conceptual models.

Bio-Material

There is a huge amount of research being conducted into the potential of 3D printing bio-materials for a host of medical (and other) applications. Living tissue is being investigated for developing applications that include printing human organs for transplant, as well as external tissues for replacement body parts. Recently, engineers at Harvard developed a novel combination of bio-inks that can be used to print tissue that mimics human tissue, complete with blood vessels.

Food

Experiments with extruders for 3D printing food substances has increased, chocolate being the most common and desirable. There are also printers that work with sugar, pasta and meat. Research is being undertaken to utilize 3D printing technology to produce finely balanced whole meals.

Bone

3D printed "bone" has already been used to replace 75 percent of a man's skull using plastic, and to replace a vertebra in a 12-year-old boy with a titanium implant.

Skin

Soon, burn victims and others in need of skin grafts could have new skin printed out for them.

Medication

By printing capsules that can be swallowed, 3D printers could allow pharmacies to manufacture your medicine on the premises, and to create custom dosages based on a patient's needs.

Sandstone

Unlike 3D printing with plastic, sandstone offers a rich and vibrant array of colors, making it an increasingly popular choice for action figures.

Glass

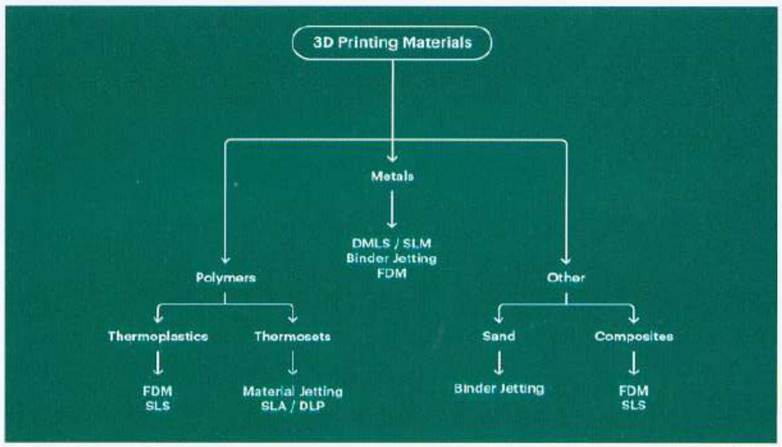
3D printing with glass involves the use of recycled glass powder, which is spread out on a bed and sprayed with a binding agent.

Flexible Filament

3D printing materials usually seek to be rigid and strong. However, strength and rigidity are not always the end goal, and that's where Flexible Filaments come in. They produce rubber-like, flexible prints. It becomes flexible when it is put in hot water. It can then be reshaped or molded into a tight-fitting spot before it cools and becomes rigid again. Flexible filaments work well for producing wearable prints, flexible joints, phone covers, and toys.

Wax

Wax 3D prints are used with SLA or PolyJet resins as an important stage of the production process rather than as an end product. Complex structures that need supports while being printed, use waxes that can be melted off the final product. Wax 3D prints are used in the dental medicine industry for casting various dental appliances.



Refer Glossary

5 3D Designing using TinkerCAD Software

How to create 3D model using open source software – TinkerCAD?

3D Printing is an incredible innovation. However, to actually put it to use, you will need to be able to create files that can be processed by a 3D Printer.

This usually takes two steps:

1. Creating a 3D Model using a CAD Software

2. Creating the layer-by-layer breakdown of the 3D Model for the 3D Printer. Also known as G-code.

In this section, we will first understand what CAD software is and how we will be using it to create a compatible 3D Model. We will also discuss some dos and don'ts that one should keep in mind while designing models for 3D Printing.

What is CAD?

CAD stands for Computer Aided Design. It is a technology developed to automate the process of drafting, or making technical drawings. It gives the user the ability to create 2D and 3D designs with great accuracy, the ability to visualize and modify the design in a virtual space before the actual manufacturing of the object. It is commonly used by architects, engineers and designers for various purposes such as creating the floorplan of an apartment, automobile design, product design, and many other applications.

There are a variety of CAD softwares available with different features that make them unique. We will start with a beginner-friendly software called TinkerCAD.

TinkerCAD is a free, online 3D Modelling software that runs in an internet browser and is well known for its simple interface and ease of use. Since its introduction in 2011, it has become a well-known platform for creating 3D models and for teaching concepts of CAD in schools. It was founded by Kai Backman and co-founder MikkoMononen. By 2017, Autodesk merged TinkerCAD and 123D circuits together into a common platform where you could design 3D models as well as circuits.

Now let us look at how we can access this platform to create 3D Models.

How to create 3D model files?

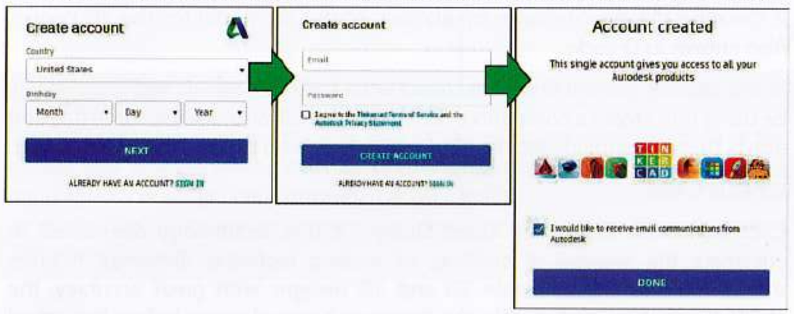
Generally 3D model files are created with 3D model software. There are a lot of software options: some are web-based and some desktop based. This class is an introduction to TinkerCAD, which is web-based software used to create and share 3D model files. What makes TinkerCAD so great is how easy it is to use. If you can click and drag, then you can use TinkerCAD!

Getting an Account

1. Open the Internet and type in: www.tinkercad.com
2. Follow the steps to create your own account :

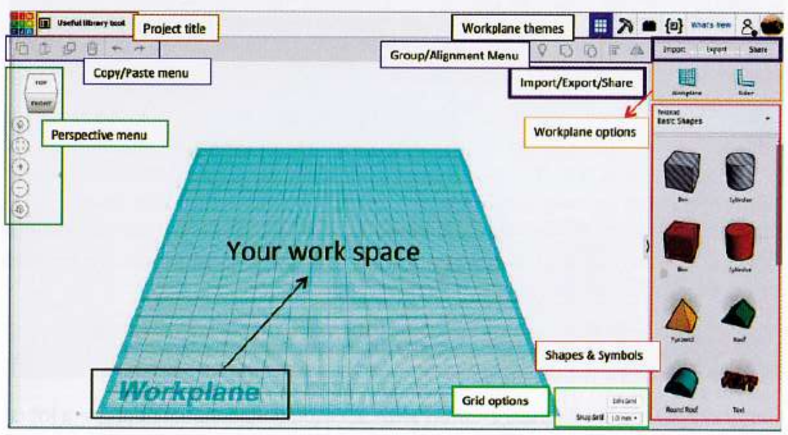
Type of Account: Educator, Student, Personal (Create this one)

Options for Sign-Up: Autodesk Sign-in, Gmail Account, Facebook Account.



3. Skip the tutorial and click on 'Create New Design'

Tinkercad Workspace Overview



Some Basic Shape Menu How-tos

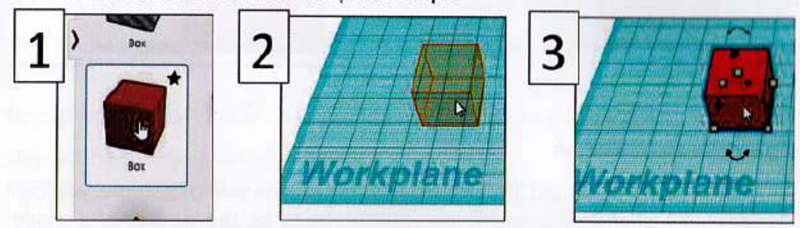
I. Moving a shape or symbol from the basic shapes menu to your Workplane (clicking and dragging)

a. Select the shape you would like to add to your Workplane.

b. Move your mouse over the Workplane where you would like to 'drop' the shape.

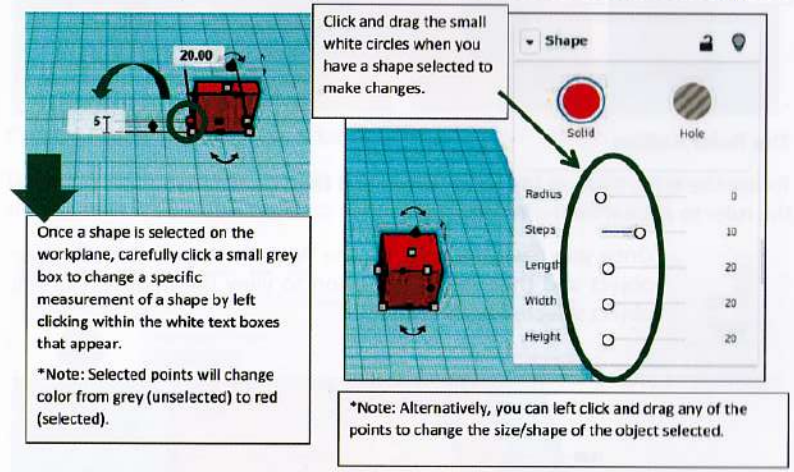
c. Left click to 'drop' shape and add it to the Workplane.

Note: Alternatively, you can left click and hold the shape you want, drag the mouse to where you want to put it on the Workplane and then let go of the left click button on the mouse to drop the shape.



II. Resizing the shape.

a. There are many different ways to edit the shape once it is on the Workplane.

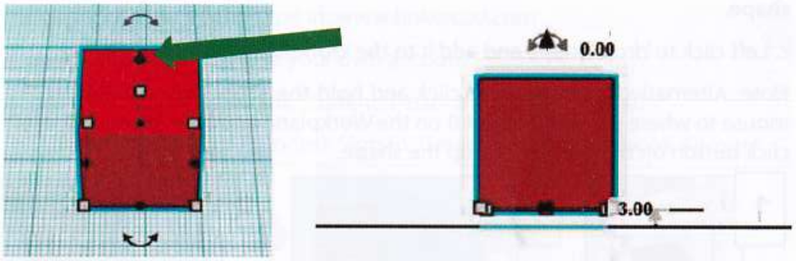


III. Moving a shape above or below the Workplane.

a. You can move a shape above the Workplane by clicking and dragging the cone-shaped handle above the shape. This function allows you to stack shapes on top of each other.

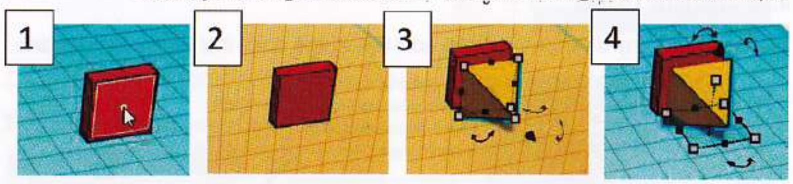
b. Remember to view the shape from the front to make sure that it is not floating above the Workplane. This could mess up your 3D print if the base of

your project isn't touching the Workplane.



The Workplane Button

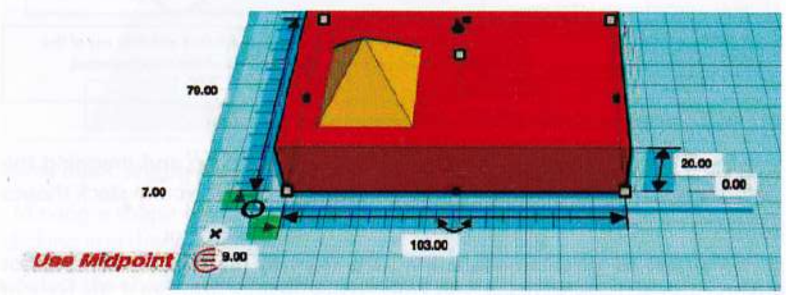
If you would like to work or build on the side of a shape, you can change Workplane the Workplane to be the surface of a shape side by clicking this button and then clicking the side of a shape.



The Ruler Button

To use the ruler, click on the ruler button and then click where you would like the ruler to appear on the Workplane.

Once you have the ruler on the Workplane, you can select an object and then have the option to view the midpoint of the object selected or the endpoint.



Your Turn to Become a Master Builder

Start with a basic house (if you want to be really fancy, add a chimney).

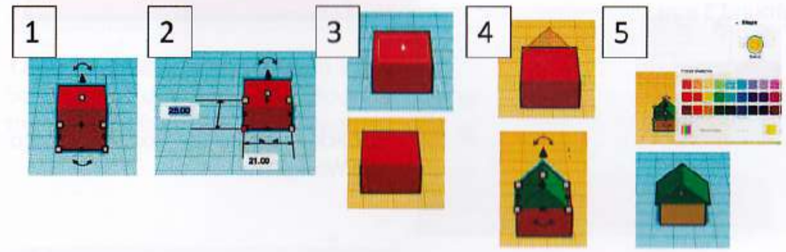
Step 1: Click and drag a 'Box' shape from the Basic Shapes menu to your Workplane.

Step 2: Change the size of your box to be the size of house that you prefer.

Step 3: Change the area of your Workplane to the top of the box in order to add your roof.

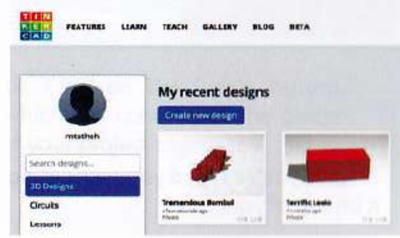
Step 4: Add a 'Roof' shape on top of your box shape to make a house.

Step 5: Change the color of the house.



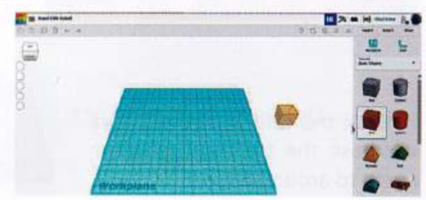
Creating your First Project: A Keychain

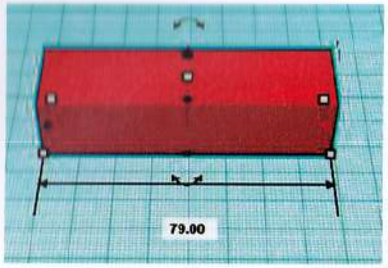
The best way to learn a new skill, is by practicing. And to practice what you've already been shown, we're going to create a personalized keychain.



1. Click on the 'Create new design' button

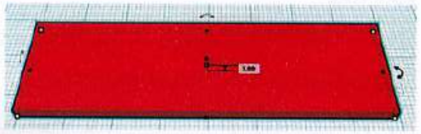
2. Click and drag a box onto the Workplane.

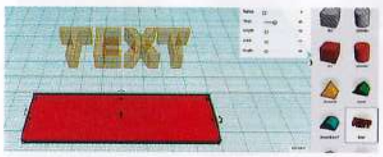




3. Click and drag the box into a rectangle, roughly 77 mm long by 22 mm deep

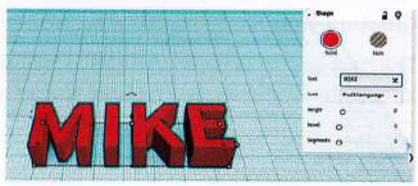
4. Grab the middle handle and reduce the height/thickness to around 3 mm.

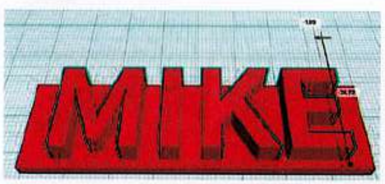




5. Click and drag the Text shape onto the Workplane

6. Type in your first name in the text box in the Shape menu that appears. If your first name is long, you can click and drag the side of your box to make it longer.





7. Once you've typed you name, drag it on top of your box.

8. Click the middle handle and decrease the thickness of your name to around 6 mm.

9. Scroll to the bottom of the Basic Shapes menu and drag a tube onto the Workplane.

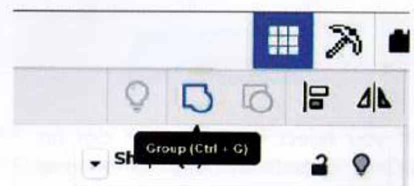
10. Click and drag the middle handle to reduce the thickness of the tube to around 3 mm.

11. Drag the tube and place it so the bottom 1/4th or so is inside the box.

12. In the Shape menu, click on the Solid colour dot, and then choose the color red from the colour menu.

13. Click and drag a square around your entire project.

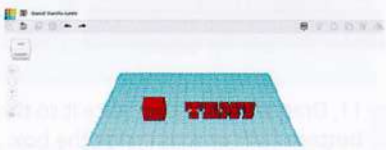
14. Click on the Group button, which will connect all the pieces of your project together.

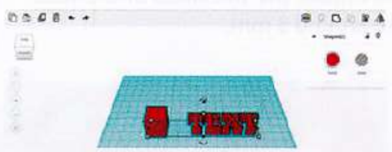


15. Admire your finished keychain!

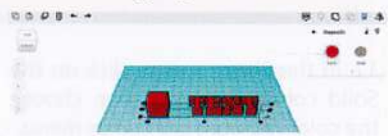
Aligning the objects on the work plane

- Drag the objects that you need to work with on the work plane. Work on them as required by you and to align them, use ctrl + A, or by selecting the objects drag your mouse over them. The objects will highlight the coordinates of settings for making any changes indicating the selection of both the objects

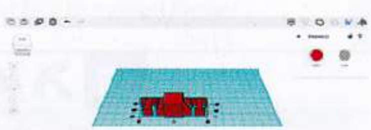




- Now click on the align button on menu bar it will highlight the coordinates

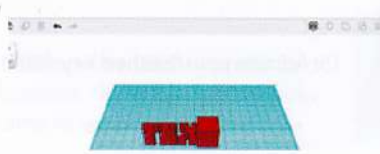


- The dark circle dots will be visible in all dimensions i.e, x, y and z coordinates
- Select the dark circles for aligning the object
- Select the first most coordinate on x axis, to align towards that dark circle point



- If you select centre dot on x axis, objects will align at centre as shown

If you select extreme right dot on x axis, objects will align to extreme right as shown



Make the required changes and click anywhere on the work plane all objects aligned will be placed accordingly and then click on group button to save the alignments.

Changing your Project Name

You will notice that Tinkercad automatically assigns any new project you create a name - usually something silly sounding. You can change you project name by clicking on the Tinkercad-assigned project name in the upper left corner of your screen:

Once you click on the name, it becomes a highlighted text box that you can then type over and rename your project whatever you'd like.

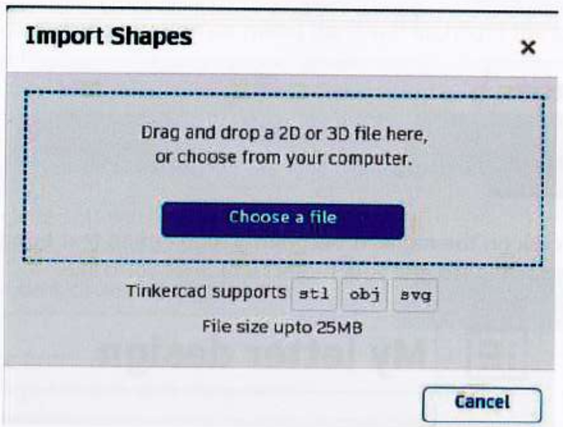
Saving your Project

Saving a project you create in TinkerCAD is easy because it's automatically done for you. When you choose to exit your project, you'll see a small green bar appear at the bottom of the screen that says Saving your work. Note, until you download your project, it's saved in the cloud (i.e. servers at TinkerCAD).

You will use the Import button to drag and drop a 2D or 3D file, or you can choose one that you have saved from your computer.

- You can download files you want to modify from 3D repository websites (like Thingiverse and MyMiniFactory) onto your computer and upload them into your TinkerCAD account here.

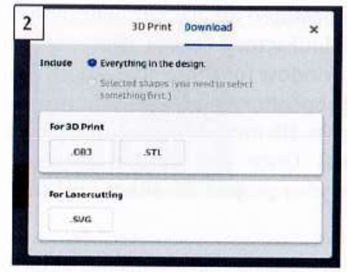
- You can also upload pictures saved from online that you want to turn into 3D objects.



When you are completely finished with your project, you will likely want to save it outside of TinkerCAD, for later 3D printing. When you're ready for this step, click on the Export button and follow these steps.

3D Print download include everything in the design. Send to my printer

1. Once you click the Export button, a menu appears giving you the option of 3D printing of your project if you have a MakerBot brand 3D printer. If you don't, or if you simply want to save your design, click download from this same menu.



2. Once you click on download, you'll be given a number of options. Choose to save your object in either the .OBJ or .STL format.

What Are .STL and .OBJ File Formats for 3D Printing?

.STL

.STL format is one of the most commonly used file formats for 3D printing. This is due to the fact that most CAD software has the feature of exporting models in .STL format and most 3D printers support it. Specifically, it is a file which 'slices' a 3D model into a series of very thin 2D 'layers.' This output is then used to drive a stereolithography (or similar) machine which produces physical prototypes through layer-by-layer deposition. The file generates the surface geometry of the modeled object only.

.OBJ

.OBJ format is considered to be more complex than .STL file as it is capable of representing texture, colour and other CAD attributes of the three-dimensional object. OBJ is also easily exported from most CAD tools and is supported by 3D printers.

Which to Choose?

.STL seems to hold a top spot in the list of preference of file formats for 3D printing. The main reason is that this type of file is simpler to use and most mesh repair tools work better with STL files than .OBJ. On the other hand, if you are willing to print a multi-color 3D model, you would want to choose .OBJ file format.

Share

The Share button allows you to share your design with others in a number of ways:

1. Snapshot of your design: You can take a snapshot of your design and post it on Facebook. You can also take a snapshot of your design and download it onto your computer.

2. Share: If you have created an account with either Thingiverse or MyMiniFactory these buttons will take you to a login window for those sites. (both are popular 3D model repository websites, where you can upload your own 3D model files or download other creators' files). Once you log in, you can automatically share your project on either (or both) sites.

3. Share over IM or email: Clicking this button generates a link you can then send to other. People with this link may view and make changes to your design

Top Menu Overview

The menu at the top right hand corner of your screen features a number of different functions and options.

Design: This is the default screen which shows the standard workplane for your 3D designs.

Blocks: Allows you to design and view your work in 'Minecraft' style.

Bricks: Allows you to design and view your work in 'Lego' style.

Shape generators: With this function, you can create your own shapes using Javascript and save them to be used later by you or the TinkerCAD community.

What's New: Check out descriptions and modeling of the newest features in TinkerCAD.

Collaborate: Click this button to share your work with others.

You: Your user profile. This button is a shortcut to your account page, to create a new design, to check out your designs, to view your notifications, change settings in your profile and log out.

Logging out/Logging back in with Saved Designs

1. To log out of your TinkerCAD account, click on the main TinkerCAD button on the top left of your screen.

2. Click on the silhouette button on the top right corner of the screen. On the drop down menu that appears, click Log out.

Tips and Tricks for Designing in TinkerCAD

1. In right side menu in TinkerCAD designing environment, click on 'Basic Shapes' and then select all from Feature Shape Generator. There you will find many amazing designs to work on.

2. Always use mouse while designing. It is very easy to move, rotate and navigate in TinkerCAD with the help of mouse

3. Use Group, Align and Duplicate options to do smart designing.

4.You can invite others to work on the same design simply by sharing your design link by email. From your design environment go to Share > Generate Link & then share the link on email.

Notes

1. TinkerCAD is a cloud based designing platform so you don't need to worry about saving your files. It will automatically get saved online and you can access it from anywhere by just logging in your account.

2. TinkerCAD is an open-source platform and it is free of cost. There are other softwares also which can be used for designing and making files for 3D printing.

6 Softwares for 3D printing

- Autodesk
- Meshlab
- Creo
- Solidworks
- Rhinoceros
- Fusion-360
- Onshape

If you are looking for the best tools you can use to modify or repair your .STL files before you send them to print, here is a list of the best software currently available:

- Netfabb
- Meshmixer

The process of converting an .STL file into machine language (G-code) is called slicing. Here are some of the best and most popular slicing software available.

- Cura
- Simplify 3D

If you are new to design (or if you are simply looking for something to print fast), then one of the many online repositories might already have what you are looking for.

Thingiverse: The largest online repository with thousands of free 3D printable files for desktop 3D printing.

MyMiniFactory: A popular online repository with free 3D models that are tested for quality and are guaranteed to be 3D printable.

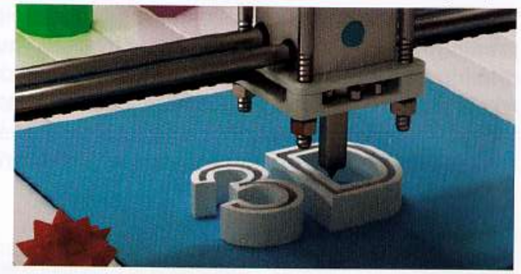
Cults: An online marketplace with high quality 3D printable models by professional designers, and curated collections connected to big-name brands.

Pinshape: An online marketplace with both free and premium 3D printable files, focusing mainly on hobbyists.

GrabCAD: An online repository of many 3D models that also includes some 3D printable files, focusing mainly on engineering professionals.

CollabCAD: This software is free and designed specially for Atal Tinkering Labs (ATL) in schools of India. The schools need to register using their ATL id. Complete software learning ebook can also be downloaded from this portal.

7 Choosing the Best 3D Printing Software



With a ton of tools available in the market, it's crucial to know what sort of tool would work best for your requirements. Following are a few things that you must keep in mind before choosing the right 3D printing software:

- Customization – Always look for customization features like sculpting, edit history, and the ability to leverage 2D models to create 3D models. Excellent customization features will help you create more stunning 3D model prints.
- Collaboration – 3D design software with cloud capabilities will empower you and your team to collaborate more efficiently over 3D models and design tools. With the cloud, users can also leverage the software from anywhere to assist in 3D modeling and printing.
- File Format – The more file formats the tool supports, the easier it gets to import and incorporate new elements into the 3D model.
- Simulation – The simulation feature through Virtual Reality (VR) can help designers to find gaps and errors in the design at a starting phase. It helps by letting you view model histories and saves time and resources.
- Scalable – Look for a 3D modeling software that offers powerful adjustment tools to efficiently scale the design of the 3D model to any limits. It would enable you to create 3D models of any shape and size.

Additionally, there are other terms to be familiar with:

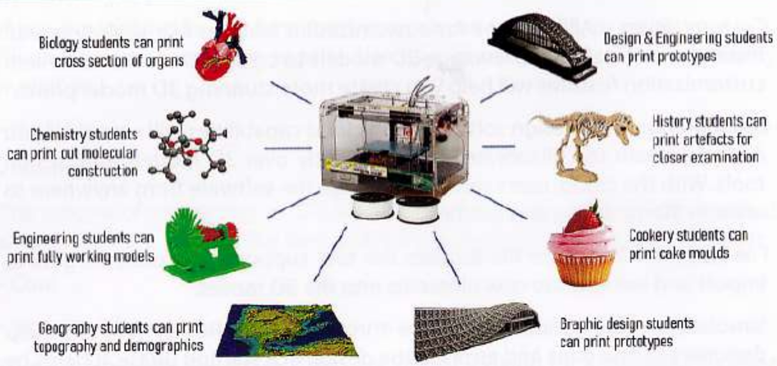
- Parametric 3D printing: Refers to the model being defined by individual parameters (specific lengths, heights, and widths, which are editable during and after the modeling process.
- G-Code: A standard programming language for 3D printers that contain commands to move parts within the printer.

8 Applications of 3D Printing

3D printing encompasses many forms of technologies and materials as 3D printing is being used in almost all industries you could think of. While 3D printing has been around for decades, it has surged in popularity and usage in recent years. New 3D printing applications are constantly being developed but the applications detailed below have recently risen in popularity. The following are just a few of the countless ways in which 3D printing technologies impact our world today.

Education

3D Printing In The Classroom



It is now evident that 3D Printing has its place in education and it will continue to have a significant impact in the classroom. Recently more schools are incorporating 3D printing in their schools in India. Atal Tinkering Labs (ATL) in schools are promoting emerging technologies, which include 3D printing as one of its major component. The benefits of 3D printing for education are that it helps better prepare students for their future by allowing students to create prototypes without the need for expensive tools. Students learn about 3D printing applications by designing and producing models they can hold.

3D printing bridges the gap from ideas and images on a page or screen to creating those ideas/images in the physical, 3-dimensional world. 3D printing tools are also revolutionizing STEM education by offering the ability for low-cost rapid prototyping by students in the classroom as well as fabricating low-cost high-quality scientific equipment from open hardware designs.

Prototyping And Manufacturing

3D printing was first developed as a means for faster prototyping. 3D printing technology greatly reduces the lead times required in traditional manufacturing, allowing a prototype to be fabricated in hours, not weeks, and at a fraction of

the cost. The automotive and aerospace industries are just two industries involved in manufacturing, taking advantage of advances in 3D printing technologies. Some non-critical parts are already used on aircraft i.e. guide vanes and parts inside the combustion chamber, fuel collectors, injection nozzles and fuselage panel.

Medicine

In the last several years there have been many 3D printing applications in the world of medicine. They range from bioprinting – where biomaterials such as cells and growth factors are combined to create tissue-like structures imitating their natural counterparts – to medical devices like prosthetics.

Construction

Construction 3D printing offers various technologies that use 3D printing as the main way of fabricating buildings or construction components.

3D printing applications that are used in construction include extrusion (concrete/cement, wax, foam, and polymers), powder bonding (polymer bond, reactive bond, sintering) and additive welding. 3D printing in construction has a wide array of applications in the private, commercial, industrial and public sectors. Advantages of these technologies include allowing more complexity and accuracy, faster construction, lower labor costs, greater functional integration, and less waste.


India's first 3D printed house in Chennai

The first fully completed residential building was constructed in Yaroslavl, Russia in 2017. In 2016, the first pedestrian bridge was 3D printed in Alcobendas, Madrid, Spain. Indian 3D printing industry witnessed a significant milestone with construction of India's First 3D printed house in Chennai by Tvasta Manufacturing Solutions, a start-up founded by IIT-Madras alumini.

Art & Jewellery

3D printers allow jewellery makers to experiment with designs not possible with traditional jewellery making methods.

9 Glossary

ABS	-	Acrylonitrile Butadiene Styrene
AM	-	Additive Manufacturing
ASTM	-	American Society of Testing and Material
CAD / CAM	-	Computer-aided design / Computer-aided manufacturing
CAE	-	Computer-aided engineering
DLP	-	Digital Light Processing
DMD	-	Direct Metal Deposition
DMLS	-	Direct Metal Laser Sintering
EBM	-	Electron Beam Melting
EVA	-	Ethylene Vinyl Acetate
FFF	-	Freeform Fabrication
ISO	-	International Organization for Standardization
LENS	-	Laser Engineering Net-Shaping (Trademark of SNL, licensed to Optomec)
LS	-	Laser Sintering
PLA	-	Polylactic Acid
RE	-	Reverse Engineering
RM	-	Rapid Manufacturing
RP	-	Rapid Prototyping
RT	-	Rapid Tooling
SL	-	Stereolithography
SLA	-	Stereolithography Apparatus (Registered Trademark of 3D Systems)
SLM	-	Selective Laser Melting
SLS	-	Selective Laser Sintering (Registered Trademark of 3D Systems)

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